Part 2: Composting Systems

The phrase "compost happens" is true. Organic matter decays. This is a natural phenomenon that happens with or without people. Nature disperses nutrient rich materials abundantly, however, humans tend to concentrate them on scales far greater than nature ever would, requiring a thoughtful and managed approach to rot. This is how composting came to be. Through rigorous science and the process of trial and error, various approaches and technologies have been developed to best manage the composting process.

There are many types of composting systems, large and small, and everything in between. Regardless of size, well managed composting systems share a few components. Adequate microorganisms and necessary to digest organic materials, as well as adequate oxygen, adequate moisture, adequate food for microorganisms (that is, a balanced carbon to nitrogen ratio), diversely sized food particles that provide pore space for oxygen to travel, and an adequate volume of material to best allow the microbial population to grow and thrive (usually a cubic yard or more). Food scraps represent materials high in nitrogen; thus, any food scrap composting program must find adequate supplies of carbon-rich materials such as wood chips, straw, leaves, and brush. In addition, compost needs time and space to stabilize and mature after an initial phase, typically characterized by high temperatures, and frequent monitoring and management.

Several basic types of composting configurations are used by community-scale and farm-scale operations:

1. Turned windrow composting
2. Bin systems
3. Aerated static piles
4. Passively aerated static piles
5. In-vessel
6. Static piles
7. Vermicomposting

These systems, which are not mutually exclusive and can be used in combination with each other, are summarized below. Table 2 (Part 3, page 29) lists the composting systems and estimated volumes handled by select community-based operations. Note: this guide is not intended as a manual on the art and science of composting, or as a comprehensive evaluation of the myriad systems available. We recommend all community compost sites have volunteers and operators trained in the best management practices of composting. (See Resources, page 120, for training resources.)

Building a windrow by hand at Red Hook Community Farm (Brooklyn, NY)

Turned Windrows

» Growing Power, Red Hook Community Farm, Farmer Pirates Cooperative, Earth Matter NY, Lower East Side Ecology Center

By far the most common technique for composting beyond home scale is the turned windrow method. A windrow is an elongated pile, which is generally turned or "rolled" from the side with a bucket loader, tractor, or a specially engineered machine called a windrow turner. Windrows can also be turned by hand. The long shape of a windrow makes the piles easy to turn and provides surface area for passive airflow into the compost. Windrows also provide a simple

Celebrating a finished windrow built at Red Hook Community Farm (Brooklyn, NY)

Tractor turned windrow at Highfields Research & Education Site. See: Compost Pile Turning video in Highfields Resource Library.

means to organize a compost site, by combining and tracking materials of a similar age in a scalable volume.

Several of New York City's community composting sites started with manual turning of windrows. Teams of volunteers with shovels would get together to turn a windrow and take part in the action of managed composting. Some sites now use skid-steer loaders for turning (e.g., Earth Matter and BIG! Compost) and are permanently staffed with 5-day workweeks. Red Hook Community Farm continues to hand turn piles. Avoiding machines when possible can help some programs meet their core goal to use sustainable practices. In addition, when machines are introduced, volunteers may disappear, undercutting public education and engagement goals.

Like the bin systems described below, human-turned windrows lend themselves to engaging volunteers. Windrow systems may allow larger amounts of materials to be handled than in bin systems. Instead of managing 2-person teams, sites may have 10-person teams turning and managing windrows with low-cost equipment such as wheelbarrows.

Bin system at the Craftsbury, VT Outdoor Center

Bin Systems

» DC Public Schools, Earth Matter NY, Lower East Side Ecology Center, NYC Compost Project

Composting in bins is probably the most common style for backyard home-scale systems. The concept applies to larger volume systems as well; bins are commonly used for demonstration sites, community gardens, neighborhood drop-off networks, and K-12 schools. Composting material is contained in a wire bin, a bay with sides, or any number of configurations that provide walls to support the compost pile in order to fit more materials vertically into a smaller space. The material is turned for aeration and can be accessed from an open side or a door/hatch for loading and unloading.

Container-based bins can be plastic and take different sizes and shapes. Many of the systems designed for backyard use are roughly the size of a garbage can and may look like a tall box. They require the user to aerate the contents by some means, either dumping out everything and turning it back inside, or using a pitchfork or specialized auger on the inside. Materials in bins with volumes less than 3'x3'x3' will not heat up to the 120-150 degrees F considered optimal for well-managed systems. "Cube-based" bins – typically at least 3'x3'x3' – are larger in size than containers and can more reliably achieve the volume necessary for the material to heat up, which reduces pathogens and seeds and accelerates decomposition. While several off-the-shelf brands are available for container-based bins, cube-based bin systems are typically custom built (many open-source designs exist). They are commonly made from wood and chicken wire or hardware cloth, and can be constructed from repurposed materials such as pallets or concrete blocks.

Many community-based sites choose a bin system because it is easy for inexperienced or untrained volunteers to use. Once a bin is full, it is considered a "batch" and no new material is added to it unless the recipe needs adjusting. Each batch is rotated to the next bin, which is typically how the pile is turned.

It is common to have three bins, with the first bin being the place where fresh material is added. Once the first bin is full, a batch is done, and it gets turned into the second bin, and then into the third bin in a constant succession based on the rate of input.

At sites in cold climates like Vermont, insulating the bins can be effective at maintaining high temperatures even in the dead of winter (see Designing a Bin System for Hot Composting, www.highfieldscomposting.org).

Bins can be utilized on large scales too, often as a way to organize aerated static pile (ASP) systems. The concept is the same; maintain distinct batches and use space efficiently by containing material vertically on less of a footprint. In such instances, the aeration pipes are commonly placed at the base of the bins, often in trenches. A large version would be a concrete box with one end open to allow for a bucket-loader to add or remove materials.

A Word about Regulations and Facility Management Requirements

Rules governing composting vary from state to state. Many states that recently revised their permitting requirements for compost operations have exemptions for small-scale and on-farm sites. But many states require all sites to meet performance-based standards, meaning operators shall not create public nuisance odors, generate pathogens, or pollute groundwater or surface waters. The Institute for Local Self-Reliance and Highfields Center for Composting recommend that trained operators manage all compost sites.

Below: Kompost Kids have designed their own 3-bin system built from pallets with a few innovations. They line the bins with filter fabric (which is used in sewers), and use sliding rods (right photo) to hold the doors in place and to facilitate ease of removal. Both innovations make the bins more volunteer-friendly.

Myrtle Village Green, 3-bin system with corrugated metal top and gravel pad

Cats add additional rodent control at the Highfields Center for Composting.

Odor and Rodent Considerations

For community composting, particularly in urban areas, addressing odors and rodents are a paramount issue. In-vessel systems from small tumblers to larger rotating drums are generally viewed as having an advantage over open systems in their ability to control odors and be rodent proof but proper management is the key for all systems. Adequate aeration or oxygen is essential for optimizing the composting process and preventing it from going anaerobic, which can produce nuisance odors. No matter what system is utilized, operators need to ensure adequate aeration.

Windrows that are well-constructed (with a good seal of finished compost) and well-turned (on a schedule that prevents anaerobic conditions) have minimal odors. They are fully exposed, and thus easily accessed by rodents. But if constructed well—scrupulously incorporating all bits of food that may have rolled away from the pile and then sealed to a uniform depth of at least 6 inches—rodents are less interested. And if placed well, with open space all around that makes rodents nervous about predators, and turned well so rodents see no opportunity for a habitat, windrows have the potential to be more rodent-proof than bins wrapped in ¼-inch hardware cloth.

Bins and containers that are well-filled (with good blending of nitrogen-based and carbon-based material) and well-turned (on a schedule that prevents anaerobic conditions) have minimal odors. Note that for plastic containers, turning material can be frustrating, because it either has to be dumped out or assiduously augured. Further, bins or containers need to sit on a foundation that addresses any "contact water" (water that has come in contact with the active composting process). On cement, for instance, contact water can be spotted and soaked up quickly with wood shavings that are incorporated back into the bin. If a foundation, like bare earth, soaks up contact water, over time it can smell. Rodents are challenging as they chew through wood and plastic, and may take up a habitat under the bin/container even if they are unsuccessful at getting to the food. To prevent access to food, bins need a full wrap of at least ½-inch hardware cloth, including the top hatch (rats will climb the sides to get in through the top). To prevent habitat formation at the base where it's nice and warm for rodents through cold climate winters, bins need a barrier (like cement, a dug-out pit with sand, or something else inhospitable). Plastic containers need the same things, but rats can still chew through the plastic, so for the same money (after all the hardware cloth) it may be better to get a tumbler that is rodent-proof and easier for turning material.

Source: David Buckel, Red Hook Community Farm, Brooklyn, New York (personal communication, March 20, 2014). Also see David Buckel, "Guidelines for Urban Community Composting, Part A: Getting Past Odors and Rats." BioCycle, *2013, available online at: http://www.biocycle.net/communitycomposting/docs/bccc_buckel.pdf*

Aerated Static Pile (ASP)

» ECO City Farms, Red Hook Community Farm, Earth Matter NY

Aerated static piles (ASP) are compost piles with perforated pipes or ductwork underneath that are actively aerated with blowers to pull (negative aeration) or push (positive aeration) fresh air through the material. The ductwork distributes airflow evenly throughout the material. Controls such as timers and temperature sensors are used to operate the fans, which supply fresh oxygen to microbes as well as cool the material if need be. ASP systems can be small- or large-scale, and can be custom built or purchased as fully engineered systems. There are significant benefits that can come with ASP systems and, as is the case with more complex composting systems, a significant learning curve as well. Operators find temperature and moisture control to be some of the most challenging factors to manage, which is why some turning is still advisable.

ASP systems require monitoring and access to electricity (and ideally to water), but once the pile is built, there is less need to get on a tractor, windrow turner, or to shovel to provide aeration. ASP systems can save labor and equipment costs over time, and are space efficient. The active aeration helps the microbes do their job quickly, thus shortening the composting process by months. Some even cut the time in half. This means that finished compost can leave the site faster or be consolidated into less space, leaving more room for new material, thereby increasing the throughput capacity. A second space saving factor is that the material in ASP systems can be piled very closely, because there is less need for "work space," which is the space where people and equipment move in managing the material. Material can be stacked up against other batches of material. Ultimately this adds up to a great deal of efficiency in space and time.

Another advantage to ASP systems is that food scraps stay contained giving them time to break down before they are exposed through turning or moving the material. This reduces the likelihood of attracting birds or other critters, which can become nuisances or vectors. Well-designed and managed systems can also control pile temperatures in the ideal range of 140-150 degrees F. In addition, most ASP systems have a "biofilter," which is a layer of natural media such as finished compost or high carbon material. With negative aeration, an external biofilter is created; the air is pulled through the pile and then through the biofilter. The biofilter can be several feet deep and long. With "positive aeration," a biofilter layer is used to cap the surface of the pile. Either way, by filtering air from the active composting process through the biofilter, the chance for nuisance smells are reduced.

ASPs can have some downsides too, especially for community composters. Problems with particle size, moisture levels, and homogenization are harder to fix in an ASP system than in a turned windrow system. The external biofilter has to be much thicker than for turned windrows. The ASP process requires more work upfront to prepare the material, and in winter the blowers can kill a pile if they are pushing through ambient air that is too cold.

Top: An aerated static pile. Middle, bottom: BIG! Compost NYC's passive aerated static pile, located under a bridge (NYC).

Passively Aerated Static Pile

» BIG! Compost NYC, Farmer Pirates Cooperative, Roots Composting LLC

Passive aeration of compost is the process that all composting methods rely on when not being actively aerated through turning or forced aeration with blowers. This process relies on the porosity of the compost's "organic matrix" and the processes of convection and diffusion, which is why large particles that create a porous architecture are such an important factor in any composting recipe. As compost heats, it creates a "chimney effect," pulling fresh cool air into its base passively (e.g. without mechanization such as blowers).

Earth Tub in-vessel compost system at Philly Compost (Philadelphia)

Richard Hudak, farmer and designer and Brenda Platt of ILSR with the Green Drum Composter during its development at the Hudak Farm (see Lake Region Union School, profile, p. 70).

Designing the base of the compost pile so that it assists this natural process is often called a passively aerated static pile. Designs are highly variable and can be as simple as piling the material on a pile of course wood chips (which can have as much as 50% pore space) or building air channels with ductwork as one would with an ASP system. Small bin systems are often built on wooden pallets or flooring, which is itself a form of passive aeration. Particularly with larger systems that are serving the public, make sure that the channels are not providing an access point for critters. Cover the ends of plastic pipe with hardware cloth for example, allowing for air to flow while blocking rodents. As with every system, turning periodically will decrease the likelihood of critters taking up residence. Turning will also speed up the process and will create a more uniform and finished feeling product.

While static piles are commonly used in community gardens, urban farms, and other community-based projects, we do not recommend passively aerated compost that does not involve turning. "Controlled" composting optimizes efficiency and quality and minimizes odors and rodents. No reputable urban composter would leave a pile unturned. Red Hook Community Farm and the BIG! Compost site, for instance, both use turned windrows in addition to ASP windrows (Red Hook's are solar-powered). Windrows are used in both cases, one set with passive aeration and the other with forced aeration.

In-Vessel Composting

» Philly Compost, University of Louisville (repurposed dumpsters), Lower East Side Ecology Center, Lake Region Union High School, University City District/The Dirt Factory, University of Maine

In-vessel systems are enclosed systems, which on a small scale would include plastic tumblers and on a large scale would include rolling drums, containerized ASP systems, and several auger turned systems, to name just a few. In-vessel systems come in many forms, but will either be continuous flow or batch systems. Batch systems would require more than one unit if a constant input of food scraps is being added, so that fresh material is not being added to batches that are almost complete and ready for unloading.

Small-scale tumblers are often recommended for urban residential settings. They are also useful as transitional storage units for materials dropped off by walk-ins. For big sites, tumblers will not work for finishing the product. Often manufacturers' claims about how little time it takes to produce a mature compost have to be ignored.

Food Scraps Can Be Used as an Animal Feed

With the increasing focus on food scraps as a resource rather than a waste, comes greater recognition and interest in using food scraps collected from communities to feed animals, most often chickens. The practice of feeding scraps to animals was in fact the norm (and still is in many places) up until very recently in our history. There is no better use from an environmental and food production perspective than to get the material right back to a local animal. Some conscientious consumers prefer buying eggs fed on human food, recognizing both the environmental and health benefits from avoiding entirely grain-based diets. Feeding laying hens food scraps is the focus here, because of questions raised about feeding food scraps to meat birds and hogs. Both have pathogen risks that are not entirely absent with laying hens, but considered safe based on what we know about chicken biology. In some states (such as Vermont), feeding food scraps to hogs that may have come into contact with meat or are not first pasteurized is illegal. Check local laws before feeding community scraps to hogs.

There are many approaches to feeding laying hens and the approach chosen will depend on location and scale. The system needs to take into account the laying operations and a method for frequently removing uneaten scraps for composting. Vermont Compost Company is well known for feeding hundreds of chickens without grain for years. It starts by making compost with the food scraps first, then letting their birds forage on the compost. Others have a feeding area with bedding and remove the bedding and food scraps for composting at a nearby location.

In the more high-tech systems, oxygen, moisture, and temperature can be automatically controlled. In-vessel systems are popular for venues where space is limited. They can take up little space relative to other composting systems and move compost material efficiently. Nuisances such as odors and pests are mitigated through containment, aeration, and biofilters. Most in-vessel systems will require a secondary composting phase, as what comes out of the vessel will not be mature enough for most uses. However, visible food scraps and odorous compounds will be broken down for the most part at this stage. The companies that produce these systems promote the efficiency and control their systems offer. In-vessel systems can also be designed on-site, from repurposed materials, at low cost.

Top: Continuous flow vermicompost bed at the Highfields Center for Composting. The 40′ x 5′ x 2′ bed generates ~25 cubic yards of vermicompost a year.

Bottom: A handful of red wrigglers at Red Hook Community farm.

System choice will depend on the scale of the system. Do substantial research. Talk to references who have used the technology before making an investment. The upfront cost will be a roadblock for most community-scale composters, although foundations and other prospective funders may be interested in developing models for small spaces and neighborhoods. Many farms have been using rotating drum vessels for years to manage their organics, including dead livestock. Looking at a range of options as well as researching in-vessel products is advisable.

Vermicomposting (Worm Composting)

» ECO City Farms, Highfields Center for Composting, Compost Club, University of Louisville

Vermicomposting – or worm composting – involves special species of worms decomposing organic materials into a rich humus. *Eisenia fetida*, commonly called red wigglers, is the most popular species of worm for vermicomposting. Vermicomposting is commonly seen at demonstration sites, community gardens, K-12 schools, and universities.

Small worm bins can be purchased or constructed for indoor use, including in classrooms, apartments, and offices. For larger community-based settings such as community gardens or urban farms, a good vermicomposting system requires that the red worms feed off of partially composted materials that have undergone an initial phase of hot composting, which inactivates weed seeds and pathogens. Thus, vermicomposting works well for making upgraded compost.

Worms produce a compost known as vermicompost, which is not straight worm castings (worm excrement), although the two are often confused. Vermicompost is instead a matrix of organic matter, microbes from all levels of the soil food web, and worm castings and is considered higher quality than straight worm castings due to the diversity of organic matter and microbes present. Vermicompost has high levels of plant available nitrogen compared to straight compost and contains natural hormones produced in the worms' bodies that promote desirable traits in plants. People of all ages are also drawn to worms, they love them in fact, and worms as well as the numerous other creatures (springtails, psuedoscorpians) that are visible to the naked eye are excellent for public engagement and education.

An online search will lead you to numerous design concepts and videos about vermicomposting systems, but the simplest from a user's perspective will work with the worms' natural ecology and tendency to feed in the top layers of the soil and go where there is fresh organic matter. Continuous flow vermicomposting beds (often called reactors) are open boxes, usually 2-feet deep and of various widths and lengths. Fresh material is fed at the top of the box or bed and finished material is cut from the bottom with a blade. The worms tend to stay at the top, free and clear of the blade although occasionally worms will make their way out the bottom. To compost a small amount of material, these systems are excellent. The footprint required to process a large volume of compost is prohibitive, unless space is not limited. For this reason, they are not typically an option for larger-scale operations. They generally require cover as well and may require heat depending upon your location (there are worm composters in northern New York State that operate without any additional heat).

Static Pile

A compost pile that is formed and then left completely unturned is known as a static pile. They are constructed on the ground without any equipment or piping underneath, although they may be covered, for instance, by a tarp. With adequate porosity, the pile may still achieve high temperatures and maintain some level of aerobic activity. A static pile will only function properly if it is receiving sufficient airflow. Lack of oxygen will lead to anaerobic breakdown of materials and the production of methane, a potent greenhouse gas. The pile can be monitored to gauge its progress.

This is an acceptable method for some, but unturned composting would not be adequate where solid waste or organic regulations apply. In general, some level of active management is greatly encouraged to achieve a hot pile that will inactivate pathogen and weed seeds, deter pests, speed up the process, and educate and engage the public about the art and science of composting.

Static pile composting is not a best management practice for community food scrap composters. We strongly advise against an unturned approach.

"Worm bins can be low-resource wooden boxes, slowly filled until the worms reach the top, and then the worms are harvested from the top and moved to the bottom of an emptied box to start over. My worm harvester is an open wooden box with a screen on the bottom. I place the harvester box, built to be smaller, into the worm bin box, and load it up with fresh material. I just leave it for a week and the worms make their way up through the screen. I pull out the harvester box, tip the worms into a new worm bin box, and then shovel out the vermicompost left behind in the first worm bin box."

– David Buckell
Red Hook Community Farm, Brooklyn

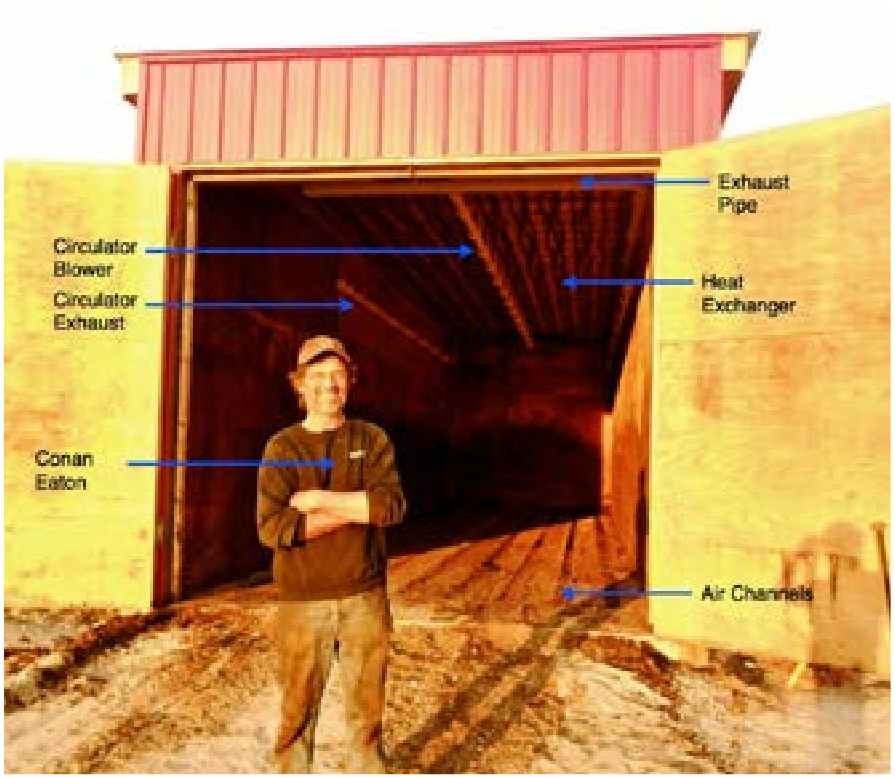
Top: The Compost Club (CA) makes worm bins that are two feet tall with corrugated plastic culvert pipe sides and plywood tops and bottoms. A layer of landscape fabric is topped with 3-4 four inches of angled 1½ inch driveway rock to provide sufficient drainage. Holes also are drilled in the bottom, and the bins are raised to prevent rotting.

Bottom: "Worm Power Fertilizer" is a bag of worm castings sold by Growing Power (Milwaukee).

SPOTLIGHT: Energy from Organics

Organic matter is full of carbon and therefore energy. This energy can be captured and released through a variety of systems, described briefly here.

Compost Heat Recovery – As aerobic microbes consume organic materials in the composting process, their metabolism generates heat, which is released into the surrounding environment. What if that heat could be captured and put to work? Several composters around the country have developed new approaches to do just this. Agrilab Technologies, Inc., a Vermont-based company, has developed a compost heat recovery (CHR) system that involves a negative ASP system pulling heat and vapor from hot compost, then using a patented heat exchanger to transfer that heat into water. This system was based on the earlier work of pioneer Bruce Fulfurd at the New Alchemy Institute and with City Soil and Greenhouse. The prototype pushed the heat and vapor into a biofilter or planter bed to supply CO^2 and heat to a greenhouse. This type of compost heat recovery is both scalable and economical.



Other heat recovery models include the "Jean Pain" Mound, and a containerized ASP system developed by dairy farmer, Conan Eaton. Vermont has literally become a hot bed for compost heat recovery systems and prototype development. The Highfields Center for Composting has a project to Hack the Heat at our research and education facility. Several other systems are in various stages of development.

Biodiesel & Waste Oil – Utilizing waste cooking oils, fats, and greases to run diesel engines is now a widespread practice and a great use for a byproduct that has energy value, is available locally, and is not a desirable feedstock to many community-based composters (although compostable). Waste oil can be processed into biodiesel fuel. Alternatively, with the right system, engines can be run directly off of waste oil.

Anaerobic Digestion – Microbial degradation of organic matter without oxygen, or anaerobic decomposition, produces different byproducts than aerobic composting. One of those byproducts is methane (CH^4), a flammable gas with high global warming potential. Cutting greenhouse gas emissions is one critical reason to keep organics out of anaerobic landfills. The controlled process for anaerobic decomposition, called anaerobic digestion (AD), captures methane for use as a fuel. Technically and biologically, AD is more complex than composting. A very specific type of microbe called methanogens generates methane, and the process involves handling and combusting a flammable and potentially corrosive gas. Nevertheless, AD is a widespread practice on a large scale in northern climates, and on a small scale in many warmer parts of the world, where proper temperatures for methanogens can be easily maintained (~100 F) at a small scale. There are also a growing number of small-scale AD models in the US, although very few would correspond in scale and scope to the community composting models covered in this guide. There is a growing interest in capturing food scraps as a feedstock for AD. Potential benefits and challenges are highlighted in Table 1, opposite page.

Table 1. Utilizing Anaerobic Digestion for Food Scrap Recycling

Potential Benefits	Potential Challenges
• Renewable form of natural gas • Many digesters have available capacity • Retains nitrogen in digestion process • Waste heat from generator for on-farm • Adds efficiency to manure "destruction" • Digesters may not charge tipping fees for receiving food scraps	• Pathogen management post digester • Requires extremely clean, pulped food residuals • Preprocessing could add costs in capture, collection, and transport • Biological oxygen demand (BOD) destruction "efficiency" determines greenhouse gas (GHG) offset values • Nitrogen loss post digester depends on effluent management strategies • Clean food residuals may be contaminated by other feedstocks in digester (e.g., municipal sludge) • Soil application of effluent returns little carbon to soil and may be limited to certain crops depending on AD feedstocks

On-farm AD system currently handles liquid food wastes, but is considering adding slurried mixed food scraps in the future.

The AD unit's electric generator is powered by methane produced with liquid dairy manure.

Waste heat from the generator is used to heat this greenhouse, which produces salad greens which are marketed to a local restaurant.